Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 18 (2011) 240–244

Physics Procedia

The Fourth international Conference on Surface and interface science and engineering

Study on properties of Aluminum film deposited on GFRP by cathodic arc technology

Dong-Cai Zhao[a]*, Geng-Jie Xiao[a], Zhan-Ji Ma[a], Sheng-Hu Wu[a], Ni Ren[a]

[a]*National Key Laboratory of Science and Technology on Surface Engineering, Lanzhou Institute of Physics, Lanzhou 730000, China*

Abstract

Aluminum film deposited on GFRP, in this paper by cathodic arc technology for decreasing the reflect wastage. The aluminum film have been characterized by pull test, Dektak 8 Stylus Profilometer, SEM、XPS、XRD and Z-82 standard four probe. The results show that the aluminum film, be compose of face centered cubic (fcc) structure, is compact, uniform. And the resistivity of film is close to bulk aluminum. The XPS spectra show that the Al-C, Al-O bonds were created in film deposition process.

Selection and/or peer-review under responsibility of Selection and/or peer-review under responsibility of Lanzhou Institute of Physics China

PACS: 68.35.Fx; 68.35.Np; 68.37.Yz

Keywords: cathodic arc deposition; metallization; Aluminum film; GFRP

* Corresponding author. Tel.: +86-0931-4585443.

E-mail address: zhaodongc@163.com.

Selection and/or peer-review under responsibility of Selection and/or peer-review under responsibility of Lanzhou Institute of Physics, China.

doi:10.1016/j.phpro.2011.06.088

1. Introduction

Glass Fiber Reinforced Plastic (GFRP), have been widely applied in the field of spaceflight and aviation, for its light weight, high intension, low expand coefficient, and can be able to endure high temperature, and so on. Whereas, the composites should been metallization in some application filed.

There are many methods of composites metallization, such as vacuum deposition, electroplating, spraying, gluing of foil，transfer, et al. And in some application field, the conductive properties will be appended when the composites made, for example, the sliver powder, metal net or metal fibers were mixed in epoxy resin, however, the mass increased. The disadvantages of electroplating, gluing of foil, transfer is low adhesion, low capability of surviving rigor surroundings; spraying is the coarse surface. High quality, such as high adhesion and large area deposition, metal films can be deposited by vacuum deposition technology.

There are some methods [1,2] of composites metallization. In this work, we deposited Al film on GFRP by cathodic arc deposition technology. The properties of film and the adhesion mechanism would be studied.

2. Experiment

All samples have been deposition by arc ion equipment with 4 pulse arc sources and 4 ion sources. The schematic drawing of the experimental arc ion vacuum unit is given in Fig. 1.

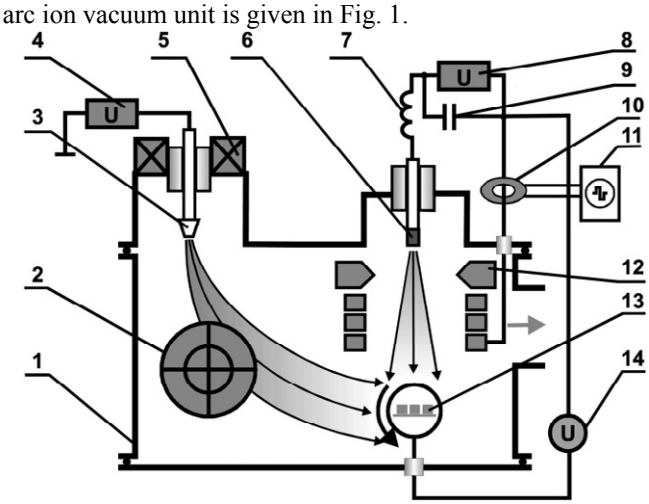

Fig. 1. Schematic drawing of the experimental unit for metal film deposition with pulse arc discharge source accelerator and filtrated arc discharge source-accelerator. (1). Vacuum chamber; (2). deflecting electromagnetic coil; (3.) metal cathode; (4.) power supply block for metal source; (5). focusing electromagnetic coil; (6). graphite cathode; (7). inductive coil; (8). power supply block for pulse arc discharge source; (9). charge intergator; (10). Rogovsky loop with integrating circuit; (11). oscillograph; (12). graphite anode; (13). substrate; (14). pulse voltmeter.

All of the cleared GFRP substrates load into vacuum chamber, and vacuumed to 1×10^{-3}Pa before Al film deposition. The distance between the arc source and substrate is 600mm, and the films growth rate is 2 μm/h.

X-ray photoelectron spectroscopy (XPS) was applied to understand more about the composition and chemistry of the interface between film and substrates, Phase compositional analysis of the sample was carried out by Origin. Model JSM-5600LV scanning electron microscopy (SEM) was used for topographic image analysis. Morphological analysis was conducted on the Al films. The crystal structure be evaluated by D/max 2400 X-ray diffractometry (XRD). The thickness, resistivity, adhesion were characterized by Dektak 8 Stylus Profilometer, Z-82 standard four probe and pull test apparatus (CMT-6104), respectively.

3. Results and discussion

3.1 Adhesion, thickness and resistivity

The adhesion, thickness and resistivity of Al films were show in table 1.

Table 1. The adhesion, thickness and resistivity of Al films

	Adhesion($N\cdot mm^{-2}$)	Thickness(μm)	Resistivity ($10^{-8}\Omega\cdot m$)
Sample	6~13	1.2	5.5~6.5

The resistivity of Al films, which was deposited by cathodic arc deposition technology, is close to the bulk Al ($2.67\times10^{-8}\Omega\cdot$m), so that the cathodic arc deposition technology is a better choice for composites metallization to increase the electric properties. The adhesion is scatter around 9 N • mm^{-2}, as show in table 1. We should pay attention is that the Al film cling to composites substrates after pulling test, and the composites had been ripped. So the film adhesion is larger than the tested value that is the adhesion between composite layers.

3.2 Topographic image and microstructure

The disadvantage of cathodic deposition is the coarse surface for the melting particulates coagulated; the advantage is high adhesion for high plasma ionization. In order to overcome the disadvantage, a deflecting electromagnetic coil was installed, as show in Fig. 1. Therefore the melting particulates and ions with large mass can not arrive at substrates, and the smooth surface achieved, as show in Fig. 2. The Al film could be deposited with a large distance between substrate and cathode when the deflecting electromagnetic coil equipped, and Al film could be deposited in a large area in low temperature.

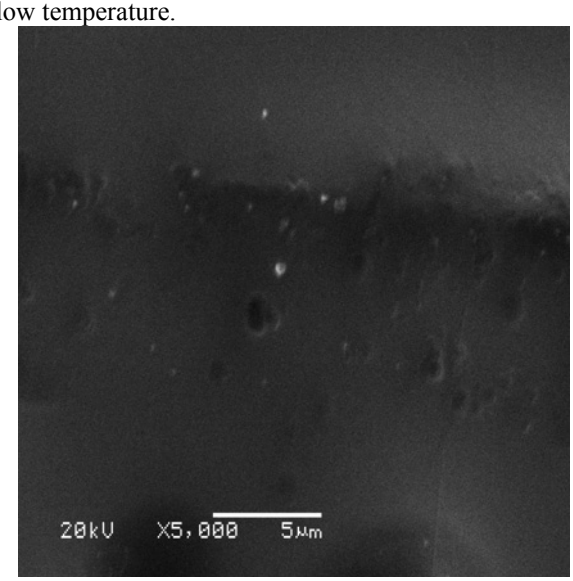

Fig.2. SEM topographic image of Al films

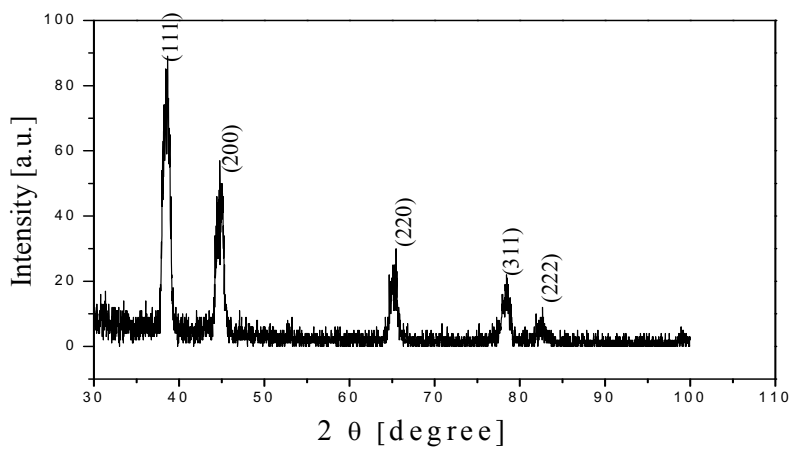

Fig. 3. X-ray diffraction patterns of Al films

X-ray diffraction pattern of Al films was given in Fig, 3. It shows that the Al film is composed of fcc, and the resistivity is close to the Al crystal. Although the film be deposited at low temperature.

3.3 Adhesion mechanism analysis

In order to study the mechanism of adhesion of Al films, the XPS data of interface had been collected, and the XPS C 1s, N 1s, O 1s and Al 2p have been shown in Fig. 4.

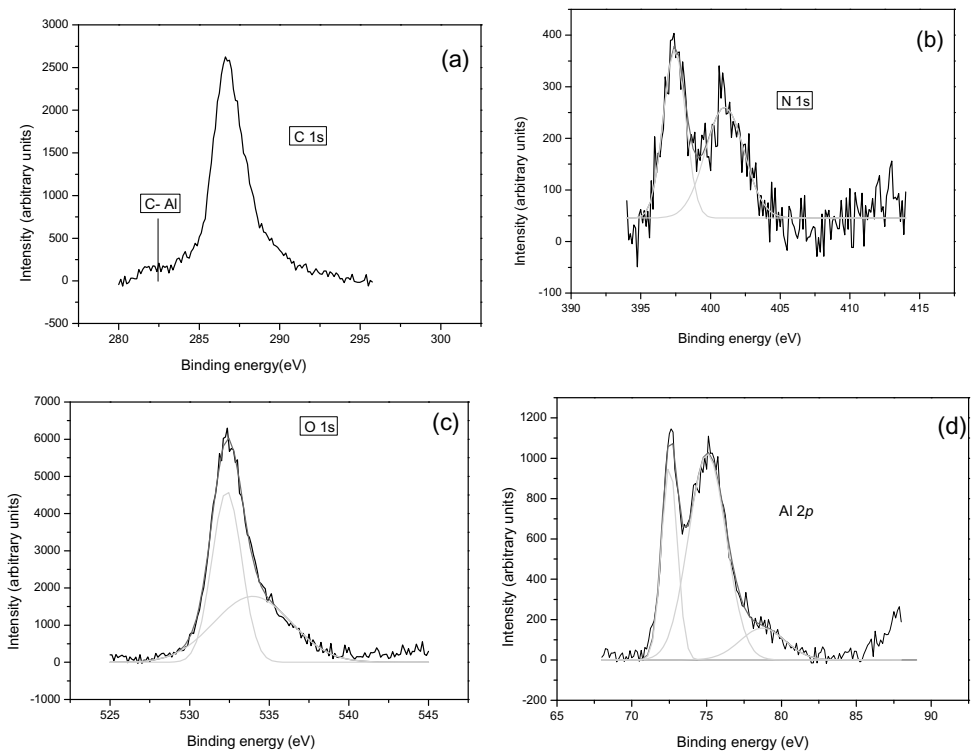

Fig. 4. XPS spectra of (a) C 1s; (b) N 1s; (c) O 1s; (d) Al 2p

The XPS spectrum of sample is show in Fig. 4, and the main peak of C 1s located at 286.6 eV that is attributed to C-N(sp^2 coordinated bonds)[3, 4], Al-O-C bonds[5], and -C-O- bonds in -COOC-[6]; the another weak peak located at low BE, is attributed to C-Al bond carbon [7, 8], as show in Fig. 4(a). In the end, we can conclude that the Al formed C-Al bonds in film deposition process, and the other BEs are attributed to the composites chemical coordinates.

The N1s spectra consist of two peaks corresponding to metallic nitride (AlN) [9] and composites chemical coordinated nitrogen, as show in Fig. 4(b). The 401.0eV peaks in Fig. 4(b) is the BE of N-O, N-C, N-H bonds in the isocyanate chemical coordinate [10,11]. So we can conclude that the N form chemical bonds with Al.

The O 1s spectra are composed of two peaks, one BE is 532.3eV, correspond to alumina [12,13] and hydroxyl[14], and the other peak's BE is 534.0eV, correspond to O-C bond in alkyl chemical coordinate[6], as shown in Fig.4(c). For that the complicated structure of substrates and the half width is larger.

From Fig. 4(d) we can find that the Al 2p spectra are consist of two main peaks. The BEs located at 72.5eV and 75.0, respectively. The low BE correspond to metal Al (the BE of fcc is about 72.8eV[13, 15]), and the high BE correspond to alumina[5, 11, 16], aluminous nitride[15], aluminous carbide[6] chemical composition. But there is another peak in high BE, 78.7eV, is clearly found, it is not clear present. In the end we can conclude that the Al form chemical bonds with other elements, such as C, N, O. Especially, the most Al are oxide, as show in Fig. 4(c), where the O come from composite, may be some few from contaminated when the composites conservation in atmosphere before films deposition.

In our film deposition process, the melting particulates and ions with large mass can not arrive at substrates for deflecting electromagnetic coil (Fig. 1), and the ionization rates increase, so that the Al-O, Al-C bonds produce. Therefore, the high film adhesion achieved, and the composites had been ripped in pulling test.

4. Conclusion

The Al film has been deposited onto composite surface by cathodic arc deposition technology at low temperature (90℃). The resistivity of smoothed Al film is close to bulk Al and the Al film is compose of fcc structure. From XPS analysis we found that the Al atom formed chemical bond with composite, such as C-Al, Al(OH)x, N-Al bonds, and the adhesion is strengthened.

And the Al films could be deposited on large area, and survived from rigor environments [17]. So the film could be applied in different situation.

References

[1] D. Mann, J. Fessmann and G. Kampschulte, M. Hopkins,Surface and Coatings Technology, 49(1-3) (1991) 168-173
[2] K. De Bruyn, M. Van Stappen , H. De Deurwaerder , L. Rouxhet , J.P. Celis, Surface and Coatings Technology 163 –164 (2003) 710–715
[3] W.J. Gammon, O. Kraft, A.C. Reillya, B.C. Holloway, Carbon 41 (2003) 1917–1923
[4] G. Iucci, C. Battocchio, M. Dettin, R. Gambaretto, C. Di Bello, F. Borgatti, V. Carravetta, S. Monti, G. Polzonetti，Surface Science 601 (2007) 3843–3849
[5] Q.D. Ling, S. Li, E.T. Kang, K.G. Neoh, B. Liu, Wei Huang, Applied Surface Science 199 (2002) 74–82
[6] www. Lasurface.com
[7] Q.D. Ling, S. Li, E.T. Kang, K.G. Neoh, B. Liu, Wei Huang, Applied Surface Science 199 (2002) 74–82
[8] Q.J. Cai, Q.D. Ling, S. Li, F.R. Zhu, Wei Huang, E.T. Kang, K.G. Neoh, Applied Surface Science 222 (2004) 399–408
[9] P.L. Tam, Z.F. Zhou, P.W. Shum, K.Y. Li,Thin Solid Films 516 (2008) 5725–5731
[10] H. Schmiers, J. Friebel, P. Streubel, R. Hesse, R. Köpsel, Carbon, 37(12) (1999)1965-1978
[11] C.D. Wagner, J.F. Moulder, L.E. Davis, W.M. Riggs, Physical Electronics Division (end of book)
[12] Gary L. Turner, R. James Kirkpatrick, Richard K. Brow, Journal Am. Ceram. Soc. 73(8) (1990) 2293-2300
[13] P.W. Shum, Z.F. Zhou, K.Y. Li, Y.G. Shen, XPS, Materials Science and Engineering B, 100 (2003) 204-/213
[14] I. Frateur, A. Carnot, S. Zanna, P. Marcus, Applied Surface Science 252 (2006) 2757–2769
[15] S. Myhra, J.A.A. Crossley, M.W. Barsoum, Journal of Physics and Chemistry of Solids 62 (2001) 811-817
[16] E. Paparazzo, Vacuum 62 (2001) 47-60
[17] Ren Pingyuan, Ren Ni, Ma Zhanji, Xiao Gengjie, Wu Shenghu, Aerospace Materials & Technology, 4(2007)65-69